ADVANCED ROAD DESIGN

METRICS

MONTANA DEPARTMENT
OF
TRANSPORTATION

MARCH, 1995

T50.5
.A38
1995

T50.5.A38 1995
OCLC: 671258695

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INTRODUCTION

This course is meant to introduce advanced metric road design topics such as horizontal and vertical curves, stopping sight distance, guardrail design and other advanced topics.
A thorough understanding of these topics in English units is very helpful, but not absolutely necessary.

The MDT Road Design Manual and the MDT Metric Conversion Manual are the two reference materials required for this course

METRIC PLAN SCALES

Please identify the usual plan scales for the following items:

A. Plan and profile sheets:
   1. Plan sheet scale
      1:_________ or 1:_________
   2. Profile scale
      1:_________ or 1:_________

B. Cross sections
      1:_________ or 1:_________

C. Typical sections
      1:_________ or 1:_________

Please also identify in the metric Road Design Manual the source of each of these scales (document the page number of each item).

A. Plan and profile sheet scales are found on page ________ of the Road Design Manual.

B. Cross section scales are found on page _________ of the Road Design Manual.

C. Typical section scales are found on page _________ of the Road Design Manual.

STATIONING

A metric station is __________ meters. (Source: ________________________)

Metric stationing is measured to the accuracy of ________ meters. (Source: ___________________________)

METRIC DESIGN STANDARDS

Metric design standards have changed everything from the width of the driving lane to the cut and fill slopes.

Metric design speeds are now in kilometers per hour (km/h). A roadway that was designed for 50 mph in the past would now be designed for __________ km/h. (Source: ________________________)

Stopping sight distances, passing sight distances, and actual stopping distances are all based on the new design speeds and cannot be soft converted from the former English design speeds. An interstate design speed of 110 km/h

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requires an absolute stopping sight distance K-value of ____________. (Source: ___________________________)

Metric stopping sight distances also are now taking into account downgrades. What is the maximum grade that is not compensated for in the stopping sight distance equations? ___________ (Source: ___________________________)

The metric design has adopted a new standard traffic lane width. This width is _____________. (Source: ___________________)

A cut stake height of 3.7 meters on an interstate design would require what rate of back slope? _____________ (Source: ____________________)

The metric ditch section has dramatically changed in design. Please sketch the new metric ditch section below and state the source of this data:

Surfacing thicknesses on typical sections are now measured in certain increments. This increment is __________. (Source: _________________)

Standard minimum right-of-way widths have changed under metric design. The minimum width of right-of-way for a non-NHS route with a 100 km/h design is __________. (Source: ________________)

METRIC CURVE DATA

The metric curve data has special rounding procedures. Please identify the accuracy of each item and identify the

source (page number in the Road Design Manual) for this rounding procedure:

Curve data	Accuracy	Source
All stationing (PC, PT, PI, etc.)		
Radius: (R)		
(R_c)		
Tangent: (T)		
(T_s)		
Length: (L)		
(L_c)		
(L_s)		

Vertical curve data has prescribed rounding procedures. Please identify the following items for accuracy and the source of this accuracy.

Curve data	Accuracy	Source
All stationing (PC, PT, PI, etc.)		
Length of Vertical Curve (L)		
Elevations		
Grades		

METRIC BID ITEMS

Many rounding procedures and accuracies are established in the metric Road Design Manual. Please identify the accuracy of the bid item to be shown in the summary frame and the source of the accuracy.

	Bid Item	Accuracy	Source
1.	Culvert excavation		
2.	Asphalt cement		
3.	Class 2 riprap		
4.	Geotextile material		
5.	Unclassified excavation		
6.	Crushed top surfacing		

7. Prime

8. Tack

9. Seeding

10. Topsoil

11. Wire fencing

12. Blue top staking

13. Guardrail steel

Culverts will be measured and paid in _________ and increments of ___________. (Source: __________________________)

CULVERTS AND DRAINAGE ITEMS

Metric design of culverts and culvert extensions has changed due to the hard conversion (physical product change) of the new metric culvert sizes.

Existing culverts will be measured and recorded to the nearest 1 mm for nominal size English culverts to be extended. (This change will be coming out with the latest Road Design Manual revisions in the near future).

Existing culverts will be shown to the nearest ________ meters in length. (Source: _____________________)

Culvert extensions are to show the new metric nominal sizes. For example, an in-place 610 mm RCP culvert will be extended with a __________ mm RCP culvert. (Source: _____________________)

Culvert excavation will be measured slightly differently for metric drainage culverts. The basic bid item is still ___________________. (Source: ______________________) The culvert excavation is determined by measuring the excavation required ___________ meters outside the culvert neat lines. For example, if we have a 900 mm drainage culvert, the width of the trench will be ____________ meters.

Minimum slopes on curb and gutter are ________%. (Source: ___________________)

An existing 60 inch CSP will need to be extended using metric pipe. What size would be used if hydraulic flow is not to be diminished?

Corrugations on CSP will now be called out in metric units. A former 3 inch by 1 inch corrugation will now be _____________. (Source: ______________________)

Riprap sizes are slightly different in metric sizes. What is the maximum size of class two riprap in metric? __________________ (Source: ______________________________)

Given the average bid cost of 48 inch drainage pipe is $60.00 per lineal foot. What should the average bid cost for one meter of this pipe cost? Also, what will be the metric size of this pipe? (Please note sources of data)

Culvert excavation has an average bid price of say $6.00 per cubic yard. What will 1 m^3 of culvert excavation cost? (Please note sources of data)

CONVERSION OF ENGLISH SURVEY DATA TO A METRIC FORMAT

Many projects that have been surveyed in English units are now being designed in metric. The English centerline can be thought of as the staked line and the metric centerline as the projected line.

Assuming the metric project design is to follow the English centerline as closely as possible. It will be shown later that the metric centerline is coincidental with the English centerline on tangent sections and that it closely approximates the English alignment in curves. (This is due to the rounding of the converted metric radius to the

nearest 0.001 meter.)

The metric alignment cannot mathematically be converted from the English alignment, so a new metric alignment must be obtained. This is done by keeping the English PI points for the metric alignment and calculating new stationing and curve data using the metric format.

The English survey cross sections and topography can be soft converted to metric survey data by multiplying the stationing and distances with the 0.3048 m/ft conversion factor. This will produce metric survey data (cross sections and topography) which can be used directly in the metric design. On long projects, the slight changes in stationing due to metric length of curves being different from their English counterparts can be taken care of with equations at the end of the metric curves (PT stationing).

This process is a little cumbersome for the designer, but saves the MDT the cost of having the project resurveyed in metric units.

DISCUSSION

Topography and cross section data is usually taken to the nearest foot for accuracy. The method described above keeps well within this accuracy tolerance.

Should the metric alignment be projected a distance off the English "staked" alignment, the same process can be used, as long as the English survey data was taken wide enough to accommodate the projected line and equations are used (usually at or near the end of metric curves) when the alignments become parallel again.

This conversion process lends itself to use of a computer program. This program is available to all designers and will convert your English data file to a metric data file.

Example Problem:

You have run a computer program to convert your English survey data to metric. Your output (in metric) looks like this:

```
533+40.11      0.98 3.0  1.37 4.6  1.86 5.5  2.22 7.6
```

Your English data was:

```
1750+00.00     3.2  10   4.5  15   6.1  18   7.3  25
```

Did the computer properly convert this data using the 0.3048

m/ft conversion factor?

FIELD SURVEY REQUIREMENTS

Projects that were originally surveyed in English units and are now being designed in metric units should request pickup survey in English units. The reason for this is that the English centerline is staked in the field and the survey crew can quickly find this line and retrieve the pickup survey.

To run in the metric centerline could take a good amount of time and may require a survey crew to run in several kilometers of alignment to pickup 300 meters of cross sections.

Metric projects that have not had any field survey completed should have the entire survey completed in metric units. What is an acceptable cross section interval for a metric survey in:

Rolling terrain?

Flat terrain?

Mountain terrain?

How far from the metric centerline should topography be taken?

These questions should all be answered in the survey request if at all possible.

METRIC OVERLAYS

A. Geometric Design Criteria

Most metric overlays will be of existing English as-built roadways. The metric design will be built to different geometric design criteria (design speed, roadway widths, etc.) as outlined in chapter 10 in the MDT Road Design Manual.

For example, with our interstate design we have several new design criteria to work with as shown on page 12(2) of the Road Design Manual.

Given our design speed is now 110 kilometers per hour we must now recalculate our existing vertical curves for adequate stopping sight distance. (Remember 110 kilometers per hour is slower than the English 70 mph design speed.)

Roadway widths will also be slightly narrower in our metric overlay. Again, referring to the MDT Road Design Manual (page 12(2)), we will use two 3.6 m travel lanes, a 3.0 m outside shoulder, and a 1.2 m inside shoulder. All of these dimensions are slightly narrower than their English counterparts and will produce a roadway less than 38 feet in width.

B. Horizontal Alignments

As was previously discussed, the metric horizontal alignment will closely follow the English as-built alignment. We are given the proper mathematical procedures in chapter 9, page 9.6(9) of the Road Design Manual. We are to calculate the metric radius to the nearest 0.001 meter and all other curve data and stationing to the nearest 0.01 meter.

An English alignment is shown on the next page. Please convert this alignment to a metric alignment, assuming this is an overlay project. Place equations in the area of the PT to allow direct soft conversion of the survey data. Note: equations are shown on page 9.6(12) of the Road Design Manual.

Curve 1	Curve 2	Curve 3
PC Sta = 94+85.7	PC Sta = 154+73.5	PC Sta = 194+98.7
PT Sta = 140+67.4	PT Sta = 165+23.5	PT Sta = 204+98.7
PI Sta = 118+07.7	PI Sta = 160+00	PI Sta = 200+00
D = 0°30′	D = 1°00′	D =1°00′
Δ = 22°54′23" RT	Δ = 10°30′ 00" LT	Δ = 10°00′00" RT
R = 11,460.0 ft	R = 5730.0 ft	R = 5730.0 ft
T = 2322.0 ft	T = 526.5 ft	T = 501.3 ft
L = 4581.7 ft	L = 1050.0 ft	L = 1000.0 ft

Find Metric Alignment:

Here is one more example problem on conversion of an English horizontal alignment to a metric alignment. Consider the following data as the as-built English data with a metric overlay.

Curve 1	Curve 2	Curve 3
PC Sta = 3+70.2	PC Sta = 10+39.7	PC Sta = 13+33.0
PT Sta = 7+24.0	PT Sta = 13+32.0	PT Sta = 15+26.7
PI Sta = 5+57.3	PI Sta = 11+91.5	PI Sta = 17+15.6
D = 13°00′	D = 13°00	D =5°45′
Δ = 46°00′00" RT	Δ = 38°00′00" LT	Δ = 22°00′00" RT
R = 440.8 ft	R = 440.8 ft	R = 996.5 ft
T = 187.1 ft	T = 151.8 ft	T = 193.7 ft
L = 353.8 ft	L = 292.3 ft	L = 382.6 ft

One of the disadvantages to this method of design is the equations. However, the benefits in this case are computer generated cross sections and topography. Another advantage is being able to quickly be able to convert metric stationing back to English stationing and vice versa. These advantages far outweigh the inconvenience of the 3 equations within the project.

We also will need to write an equation at the beginning of the project and the end of the project to tie into the existing as-built data. We should identify feet and meter units in the equations, i.e.

Sta 10+00.0 (ft) F 14-1(3)0 BK =
Sta 3+04.8 (m) STPP 14-2(3)0 AH

Should a project be a reconstruction project with the survey already performed in English units, the same method of conversion can be used. The advantages in this case will most likely outweigh the disadvantages.

C. Vertical Alignments

If a project is to be overlaid and the existing vertical alignment is to be followed, we would usually not show the profile in our plans. We would still be required to check the stopping sight distances to determine if they met our design criteria or not.

For example, consider the following situation in which an existing roadway is to be overlaid. The metric design speed is 100 kilometers per hour. Does this vertical curve meet the stopping sight distance criteria as established on page 12(2) of the Road Design Manual? Does this curve require a design exception?

Given the following data: (as-built data in English units)

If this project was a reconstruction project and the preliminary vertical alignment was the 1000 foot vertical curve shown, we would have an option of keeping the 1000 foot vertical curve and soft converting to metric or using the criteria for a new metric curve. Let us look at the soft converted metric curve first.

In this case we need the VPI data to compute new grades. (Due to rounding of elevations in the conversion process new metric VPI elevations will be established. We need to calculate new grades between the VPI's.)

If this project was a reconstruction project and we chose to pick a new vertical curve length, what is the minimum length of curve we would choose? (Hint: See chapter 10 in the Road Design Manual.)

D. Right-of-Way Plans

Should we require right-of-way or construction permits, they need to be obtained off the new metric centerline. The Right-of-Way Bureau will develop R/W plans from your metric strip map and will purchase the R/W or permits in metric units.

E. Spiral Curves

Spiral curves on overlay projects are converted to metric values by converting the R_c to metric and rounding to the nearest 0.001 m. The length of the spiral is then converted to metric and rounded to the nearest 0.01 m. All other curve data is calculated using the spiral length and R_c and rounded to 0.01 m. Page 9.6(4) in the Road Design Manual contains the spiral curve formulas.

Given the following as-built English data:

Convert the curve data to metric. For ease of calculation, assume this is the first curve on the alignment and soft convert the PI station.

Δ = 60°30′00" RT
Δ_c = 45°30′00"
D = 5°00′
L_s = 300.00 ft
T_s = 820.1 ft
L_c = 910.0 ft
R = 1146.0 ft

T.S. Sta = 270+95.4
S.C. Sta = 273+95.4
C.S. Sta = 283+05.4
S.T. Sta = 286+05.4
P.I. Sta = 279+15.5

F. Interstate Alignment

Interstate ramp tie-ins to mainline and other alignment problems specific to interstate design are illustrated in the following examples.

GUARDRAIL AND CLEAR ZONES

Clear Zones

The road design manual uses the variable clear zone as defined in the AASHTO Roadside Design Guide.

Given:

100 km/h design speed
5:1 fill slopes
1995 ADT = 5500 vehicles/day
2015 ADT = 7500 vehicles/day (design year)

Find:

A) The clear zone width on a tangent section of this roadway. (Please cite references used.)

B) The clear zone width on the outside of a 1000 meter radius curve. (Please cite references used.)

GUARDRAIL

Please determine the stationing at which to begin the MELT terminal section for the following example:

Given:

- Design Speed = 110 km/h
- Interstate design

- Fill slopes Sta 10+00 to 11+00 are 3:1
- Bridge End Sta. 11+00.00
- Fill slopes at Sta 1+00 to 9+90 are 4:1 slopes.
- 1995 ADT = 4500 vehicles/day
- 2015 ADT = 6100 vehicles/day
- Sta 1+00 to 11+00 is tangent roadway

SUPERELEVATIONS AND RUNOFFS

Transitions from tangent roadways to superelevated sections can be handled two ways. The first method will be incorporated into the Road Design Manual in the near future and is based on an overlay of an existing English designed roadway.

This method places 100% of the superelevation at the PC and PT of the simple curve. This has been our English standard for many years and if we are going to overlay a project, is the method we should use.

The second method is for new construction projects. It places 70% of the superelevation at the PC and PT and relies on the same rate of superelevation change prior to the PC to carry into the curve to achieve 100% superelevation within the simple curve. It also relies on the superelevation to transition from full super in the curve to 70% super at the PT and then back to a normal tangent section.

This method is illustrated in chapter 9 of the Road Design Manual.

The two methods are illustrated in the next examples.

IMPACTS TO OTHER DESIGN UNITS

What are some of the impacts to other design units from a metric alignment?

Please list impacts to:

1) Bridge

2) Hydraulics

3) Materials

4) Traffic

5) Environmental

6) Consultant Design

7) Construction

COURSE SUMMARY

Our intent has been to introduce some of the new metric design methods and procedures as outlined in the Road Design Manual.

We recognize that we have just begun to design in metrics and some of the terminology and procedures are somewhat foreign. With time and experience designing in metrics will become relatively easy.

Any suggestions on improvements to this course or any topics for future courses can be put on your course evaluations.

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